REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

(2)

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
2/94

3. REPORT TYPE AND DATES COVERED
Scientific Paper

4. TITLE AND SUBTITLE
Visualization Support for an Army Reconnaissance Mission

5. FUNDING NUMBERS

6. AUTHOR(S)
Tom Witte
Valerie C. Kelly

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Topographic Engineering Center
ATTN: CETEC-PA
7701 Telegraph Road
Alexandria, VA 22310-3864

8. PERFORMING ORGANIZATION REPORT NUMBER
R-213

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release;
distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The unmanned aerial vehicle (UAV) is gaining importance as a means of acquiring real-time information under difficult environmental and battlefield conditions. In Operation Desert Storm, UAVs were effective in gathering information and in searching for mobile, semi-permanent assets. UAV systems provided reconnaissance, surveillance, target acquisition, and battle damage assessment. A recent Army project integrated GPS tracking, video imaging, and 3-D visual simulation in an investigation of their benefits to the usefulness of UAVs. Construction of the simulation database entailed the use of digital stereophotogrammetric techniques to orthorectify USGS NAPP photographs. Numerous digital orthophotographs were mosaicked together and used as texture atop digital terrain elevation data to generate the simulated environment.

14. SUBJECT TERMS
UAV, real-time, reconnaissance, GPS, simulation

15. NUMBER OF PAGES
10

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	

VISUALIZATION SUPPORT FOR AN ARMY RECONNAISSANCE MISSION

Tom Witte and Valerie C. Kelly
U.S. Army Topographic Engineering Center
Alexandria, Virginia 22310-3864

ABSTRACT

The unmanned aerial vehicle (UAV) is gaining importance as a means of acquiring real-time information under difficult environmental and battlefield conditions. In Operation Desert Storm, UAVs were effective in gathering information and in searching for mobile, semi-permanent assets. UAV systems provided reconnaissance, surveillance, target acquisition, and battle damage assessment. A recent Army project integrated GPS tracking, video imaging, and 3-D visual simulation in an investigation of their benefits to the usefulness of UAVs. Construction of the simulation database entailed the use of digital stereophotogrammetric techniques to orthorectify USGS NAPP photographs. Numerous digital orthophotographs were mosaicked together and used as texture atop digital terrain elevation data to generate the simulated environment. An experiment was conducted in which a UAV flew over a test site, providing video imagery as well as reporting position and orientation to ground observers. The video imagery was compared with a computer simulation of the identical flight path. Other issues to be addressed included the ability to control the UAV via uploading of waypoints chosen from the computer simulation, the ability to track a ground-based target vehicle, and the ability to plan UAV missions rapidly via simulation.

INTRODUCTION

The cost, complexity and environmental impact of live training exercises make simulation increasingly attractive. Pilots and tank drivers can use computer-generated terrain scenes during training to save resources and provide experience in potentially dangerous or difficult situations. These scenes are produced using advanced computer graphics technology and digital topographic data. The U.S. Army Topographic Engineering Center (TEC) is researching ways to improve this technology and apply it to military mission planning and rehearsal, battlefield management and advanced weapons design.

TEC'S Battlefield Visualization Test Bed (BVTB) is an assembly of hardware and software used to develop and demonstrate visualization technology. The BVTB is designed to support the scientific investigation of visualization applications and technology transfer issues.

An ideal visualization system provides a realistic view of the battlefield, allowing soldiers to see hills, trees, roads, waterways, etc. The technology also enables the commander to create and represent complex battlefield situations rapidly and effectively. With battlefield visualization capabilities, the commander can thoroughly examine the terrain and quickly evaluate possible battle scenarios using simulated plans and maneuvers.

Today's command, control and communications systems require an integrated simulation capability to support the commander in his real-time decision making. Researchers at TEC will continue to use the BVTB to develop new scene generation techniques, and to transfer and integrate battlefield visualization capabilities into Army programs. This will help the Army train more effectively, develop weapons systems smarter and faster, plan and rehearse tactical operations more quickly, and enable the commander to see and understand complex battlefield situations.

BACKGROUND

Among the most significant lessons of Operation Desert Storm was recognition of the need for real-time battlefield intelligence. UAVs are emerging as cost effective systems for providing vital intelligence in real-time and at no risk to soldiers and equipment. In Operation Desert Storm, UAVs were especially effective in gathering information and in searching for mobile, semi-permanent assets. These systems provided reconnaissance, surveillance, target acquisition and battle damage assessment (Defence 1993).

The Joint Precision Strike program seeks to reduce the time required for reconnaissance, surveillance, strike planning, weapons delivery and battle damage assessment. TEC recently participated in a Joint Precision Strike demonstration involving UAVs. Concepts to be tested included satellite control of a UAV and its on-board EO sensor, cross correlation of live versus synthetic scenes and real-time synthetic representations of target acquisition and weapons delivery.

In this experiment, a GPS receiver and an EO sensor were mounted on a UAV which flew over a target set, providing telemetry every second. The UAV's altitude and speed were to be held constant. This information was to be transmitted to TEC and used to animate the viewpoint of a visual simulation software program that was simultaneously navigating a high resolution, 3-D database of the same area. The database consisted of elevation data textured with orthorectified aerial photographs. The UAV also was to transmit imagery with annotated telemetry data to a ground station. Live videoimagery was to be compared with the simulated scenes.

DATABASE CONSTRUCTION

Source acquisition
The location for the test was a 10-minute-by-10-minute area in the Mojave Desert, southeast of Edwards Air Force Base in southern California. The site falls within the Adobe Mountain, Shadow Mountains, Shadow Mountains SE and El Mirage quadrangles produced by the U.S. Geological Survey (USGS). These maps were based on the North American Datum of 1927 and the National Geodetic Vertical Datum of 1929.

To provide full areal photographic coverage of the site at high resolution, 21 9x9 National Aerial Photography Program

(NAPP) photographs were purchased from the USGS. Three flight strips of seven photographs each covered the test site. As digital coverage was not available, film positives sufficed. NAPP standards specify quarter quadrangle-centered photographs, exposed at a height of 20,000 feet above the ground, using a six inch focal length. These 1:40,000 scale photographs were scanned at 60 microns to produce digital images with a ground resolution of 2.4 meters per pixel.

On the NAPP imagery, of course, points on the ground are displaced as a function of their height. These relief displacements prohibited the determination of accurate linear measurements, which were required for the experiment. Accurate measurements can be made only on orthoimages of the original photographs. The goal of digital orthophotography is to present each pixel as if it were viewed from directly above, with the camera orthogonal to the ground.

Orthorectification

A digital elevation model (DEM) is needed to transform an aerial photographic image into an orthophoto image. In this process, the horizontal coordinates and elevation of a point on the ground are used to determine the position of the point on the original photograph. The gray shade assigned to that position in the digital image is then assigned to the corresponding horizontal position on the orthophoto. The result is a new digital image without relief displacement. This orthophoto image will benefit from the appearance of a photograph and the geometric properties of a topographic map. These characteristics enable the image data to be registered to the elevation data; this is essential for an accurate, realistic fly-through.

Horizontal control points were selected from the four USGS 1:24,000 scale topographic maps covering the test range. These maps have a stated absolute accuracy of 12 meters at 90 percent circular error. Defense Mapping Agency (DMA) Digital Terrain Elevation Data (DTED) provided the vertical control. Level 1 DTED (a uniform matrix of elevation values spaced 3 arc seconds apart) was used. The absolute vertical accuracy objective for DTED Level 1 is ± 30 meters at 90 percent linear error.

The digital orthorectification was performed by the Imagery Extraction Division (IED) using TEC's Terrain Information Extraction System (TIES). TIES is an integrated digital stereo image-based mapping system that uses photogrammetric GIS technology. One of the key components of TIES is the Digital Stereo Photogrammetric Workstation (DSPW), a developmental system which can be used to manage and display digital imagery and its geometric support data, aerotriangulate digital imagery, rectify digital imagery, automatically create digital terrain models (DTM) at any specified elevation point spacing, interactively edit DTMs in stereo, and to display and interactively edit digital feature data that are stereoscopically superimposed on stereo imagery.

Another component of TIES, the Image Digitizing System (IDS) was used to convert the NAPP photographs into digital images. The IDS scanner is a precise continuous scanning optical device consisting of a 2,048-element array of charge-coupled micro-sensors. The scanning resolution is chosen to equal the product of 7.5 microns and powers of two (e.g. 7.5, 15.0, 30.0, 60.0, 120.0, etc.). For this project, the imagery was scanned at a resolution of 60 microns and then written to an 8mm tape for loading onto the DSPW. Camera calibration data were also recorded at this time. The scanning process converts raw photos into pixels, each of which has an address location in the image in terms of rows and columns. However, this location is a distortion of the true ground location of the area represented by the pixel.

The digital imagery was imported into the DSPW via a frame import function. The image files and their associated support data were loaded, control points were measured and exterior orientation was performed. The points were measured using ERDAS software and a digitizing table.

Corresponding image points were measured and stored in a file.

A least squares adjustment was performed to determine the optimum sensor model to fit the measured points. Due to time constraints, a bundle adjustment was performed on each of the three strips rather than on the entire 21-photo block. This established the orientation of the camera relative to the ground. Upon successful completion of the triangulation process, the orthophotos were generated. The generation of one orthophoto for every other photo was sufficient to ensure complete coverage of the test region.

Thus, four orthophotographs were generated per flight strip. These four digital orthophotographs were added together to form four rows running east-west. These rows were digitally mosaicked together from north to south, as follows: The first and second rows were mosaicked together to form one top row, and the third and fourth rows were likewise joined to form a single bottom row. These top and bottom rows were finally mosaicked together to form a complete, orthorectified image of the test site. The mosaicking process involved some trimming away of overlapping imagery. Image enhancement was not deemed necessary for the purposes at hand, and was not performed.

The image data were given to the operator of the visualization software on a single 8mm tape which contained twelve individual digital orthophotographs at full resolution, and one file containing a one-fourth down-sampled image of the entire test site. The individual orthophotographs were slightly less than one megabyte each, and the overview took up about four megabytes. The operator needed only to know the pixel size, the number of rows and columns, and the coordinates of the southwest corner of each image in order to prepare for the fly-through process.

SCENE SIMULATION

Texture

Texture mapping is a technique used to add realism and detail to images. A texture pattern is an image that can be applied to a polygon as wallpaper is applied to a wall. In 3-D graphics, these patterns provide the correct perspective, appearing to stay glued to the underlying surfaces as the viewpoint changes. More specifically, a texture is a 2-D array of pixel information. Texture coordinates can be assigned to the vertices of polygons. The system can then interpolate texture coordinates as it fills the polygons.

The project described herein involved the use of geospecific texture - aerial imagery of the test range - as a pattern to cover the polygons defined by the terrain elevation data in a simulation. The imagery was divided into many individual tiles which were then applied to the polygons that were approximating the DTED-based terrain. The result was a photo-realistic database that provided good visual cues for depth and height. However, texture mapping is very demanding of a system's speed and memory (Latham 1992).

Visualization software
The software used for mission planning, observation and play-back was DrawLand, an in-house program used to support terrain visualization research. DrawLand behaves like a flight simulator; what is seen on the monitor changes in response to how one manipulates (via mouse or other input device) the controls of a virtual vehicle. However, the program does not attempt to mimic the flight dynamics of a specific aircraft.

DrawLand's main input is DTED, which the program can load into memory directly from CD-ROM. The user can specify the area to be loaded. Given the southwest corner and the size of the cell, DrawLand searches for the appropriate files, and can combine data from several files if necessary.

DrawLand's interactive or flight mode begins by displaying the terrain as a one-third resolution wireframe. The user can adjust the resolution at will and also vary the rendering method to suit the purpose (e.g., wireframe for speed, photo-texture for realism). The viewpoint can be controlled by a mouse. Coordinates, altitude above MSL, distance above ground, yaw, pitch and roll are displayed for the viewpoint or for a model.

During flight mode, the movement of the user's viewpoint can be recorded, as can the movement of a particular model that is being controlled. The animation can be recorded one frame at a time to an optical disk or to a hard disk. Model movements can also be played back in real time.

EXPERIMENT

The UAV flew on the western part of the range in a holding pattern. There were two potential targets - a tank and a mobile surface-to-surface missile launcher. Special forces on the ground were to locate targets and then transmit their coordinates to the mission planner operating DrawLand visualization software remotely at USATEC. Icons representing the targets were to be inserted into the synthetic scene in their proper positions to facilitate mission planning, targeting and weapons delivery in the synthetic environment. Upon identification of a target, the mission planner would define and transmit accurate waypoints for a valid flight path toward the target back to the ground station in California for subsequent uplink to the UAV.

It was planned that the telemetry would be sent from the UAV to a communications satellite, which would transmit it to the ground station, which would then send it to TEC in ASCII format via a T1 line. The coordinates of waypoints were to be sent via T1 line from TEC to the ground station, then passed to the satellite and back to the UAV. Videoimagery was to be transmitted from the UAV to the satellite and then split to both the ground station and TEC. Concepts to be tested included non-line-of-sight control for the UAV as well as the incorporation of actual targets into a synthetic environment for command and control purposes. Video and synthetic imagery were to be compared, and the usefulness and validity of live video imagery were to be assessed.

RESULTS

The UAV flew on more than one occasion; no single flight addressed all of the salient issues. Real-time tracking and video transmission did not occur simultaneously. There were some problems with the data received from the UAV, and trouble was also encountered in configuring the ports on the visualization workstation. Videoimagery and telemetry were transmitted from the UAV to the satellite and to TEC in real time; however, visualization techniques were not employed on that particular date. On those occasions when visualization-aided mission planning was to be conducted remotely from TEC, both the target coordinates and waypoint coordinates were to be passed via cellular STU-III, a secure telephone with a built-in modem. However, although the capability existed, it was not used.

GPS receiver log data were sent by modem to a PC and were downloaded for subsequent use by DrawLand. The data packets transmitted by the ground control station contained the UAV's latitude, longitude and altitude, as well as time of fix, pitch, roll, heading, airspeed, etc. Three sets of data were sent to support visualization efforts: the first set was completely bad, and the other two contained correct latitudes and longitudes only.

Black and white imagery from an early trial run was recorded on videotape and brought to TEC for comparison with simulated flights over the same area. The quality of this videoimagery was generally poor, and some new structures appeared which were not present in the synthetic scene, due to the date of acquisition of the NAPP imagery. However, the DrawLand operator was able to duplicate the UAV's flight path for a side-by-side comparison. The simulation actually was visually superior, due in part to the poor quality of the video, and to the fact that the haze and fog that existed at the test range were not rendered by the computer. A higher quality color video was recorded later in the testing process, but it wasn't used to recreate the UAV's flight.

CONCLUSION

The concept of non-line-of-sight control for a UAV and its on-board sensor was successfully demonstrated, as was the use of advanced visualization techniques to improve the UAV mission planning process. The application of real-time tracking and control using visualization via direct satellite link will extend the ranges of UAVs and improve their effectiveness to the Army. Further testing and experimentation will be done in this area. Researchers at USATEC will continue to develop simulation capabilities and to integrate them effectively into Army systems and programs. UAV systems will continue to be used to acquire real-time reconnaissance, intelligence and targeting information, not only for locating high-value military targets, such as Scud missiles, but also for applications such as treaty verification and compliance. There are numerous potential commercial applications, as well.

ACKNOWLEDGEMENTS

The authors wish to thank Daniel Carleton, Glenn Frano, Chris Gard, Bill Hubbard, Tom Jorgensen and Max Roos for their valuable contributions and suggestions.

REFERENCES

Anonymous, 1993, No Risk Snooping: Defence, Vol. XXIV (6): pp. 25-30.

Latham, R., 1992, The Preparation and Use of Texture Patterns for Real Time Graphics: Real Time Graphics, Vol. 1 (4): pp. 8-11.